Shallow Water Acoustic Experiment Analysis

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LONG-TERM GOALS

The long-term goal of the research is to increase the physical understanding of acoustic propagation in shallow water ocean environments in the 25-5000 Hz band. This includes both the physics of the seabed and the coupling of physical mechanisms in the water column and the seabed in complex range- and azimuth-dependent littoral waveguides.

OBJECTIVES

The main objective of the current research is to use macroscopic acoustic measurements such as (1) propagation loss, (2) wind-generated ambient noise, and (3) reverberation time series, to infer a more microscopic picture of the physics of the seabed in a shallow water region on the New Jersey continental shelf.

APPROACH

The central hypothesis of the research is that the fundamental properties and physics of the seabed can be inferred by acoustic measurements in the water column. The measurements require a sufficiently large bandwidth and source-receiver spatial scale with adequate physical measurements in the water column and seabed during the time frame of the acoustic measurements. The acoustic measurements have been previously described in part in Refs. 1 and 2. Values that can be interred include the sound speed and attenuation of the sediment and the bottom backscattering strength. Physical models are used to compare the predicted frequency dependence of the attenuation and backscattering coefficients to the inferred values. Inference methods include simulated annealing to locate global minima and maximum entropy methods to infer marginal probability distributions.

WORK COMPLETED

A new set of geo-acoustic inversions using acoustic data taken on the New Jersey continental shelf includes an uncertainty approach based on a maximum entropy approach. The inversion and uncertainty studies were used to establish mean values and standard deviations of important seabed parameters. The mean values for seabed environmental parameters such as the sound speed ratio and the sediment thickness were then used to obtain the attenuation versus frequency in 50-3000 Hz band. The inferred values were compared to predictions made by a Biot model. Further, model and

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14. ABSTRACT
The long-term goal of the research is to increase the physical understanding of acoustic propagation in shallow water ocean environments in the 25-5000 Hz band. This includes both the physics of the seabed and the coupling of physical mechanisms in the water column and the seabed in complex rangeand azimuth-dependent littoral waveguides

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measured shallow water ambient noise levels due to wind-generated noise referenced to a deep-water environment were found to be consistent with the previously established frequency dependence of the attenuation. Finally, the seabed properties were used to extract the frequency dependence of the bottom backscatter coefficient from reverberation data taken in the region.

RESULTS

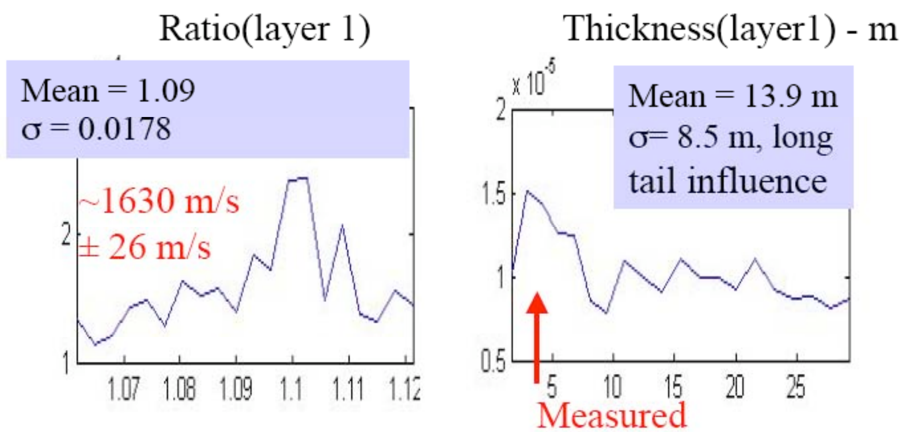

Figure 1: Marginal probability distributions for the sound speed ratio and sediment thickness of the first sediment layer dervived from data collected on 52-element array.

Figure 1 shows marginal probability distributions for the sound speed ratio and the sediment thickness of the first sediment layer. The marginal distributions were obtained using an approach based on the maximum entropy principle. The acoustic data used in establishing the probability distribution were taken on a sand ridge composed of a coarse sand layer whose thickness varied from 3-6 m[1] on a 52-element array that had both a horizontal and a vertical component. The measured standard deviation of sound speeds reported from core measurements was about 30 m/s which is in agreement with those derived from direct acoustic measurements reported by Goff.[2] While the most probable sediment thickness agrees with chirp sonar measurements, the distribution gives a mean value that is larger than the reported mean values due to the long-tail structure of the distribution. It is stressed that the relationship between measured statistics and those inferred from acoustic measurements is not well understood. The issue of the long-tail is one that could likely be addressed in the future by making better use of the prior information on the sediment thickness.

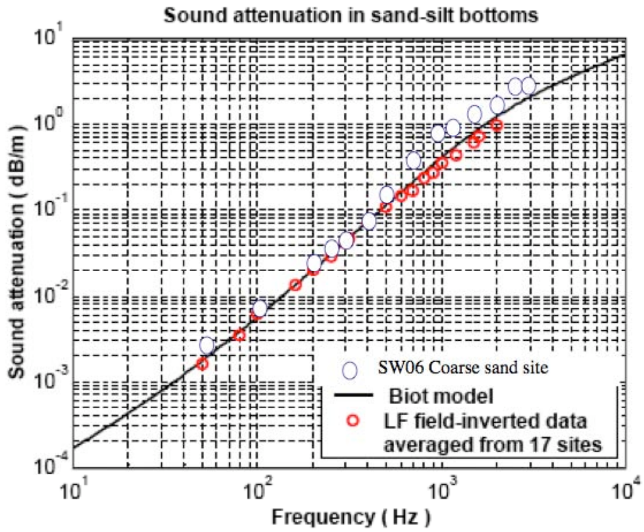

Figure 2: Inferred attenuation values compared to the average values obtained by Zhou et al. and a Biot model computation.

Figure 2 shows the inferred attenuation values for the first sediment layer as a function of frequency. For purposes of comparison Fig. 2 includes a Biot theory prediction and an average value obtained by an analysis of 17 shallow water locations.[3] For frequencies *f* below about 2 kHz the frequency dependence of the inferred attenuation is proportional to approximately $f^{1.85}$. These results are consistent with other studies that have inferred a non-linear frequency dependence of the attenuation from analyses of forward propagation data. While the data are not inconsistent with the Biot predictions above 2 kHz, one cannot draw any definitive conclusions concerning the frequency exponent because of the sparseness of data.

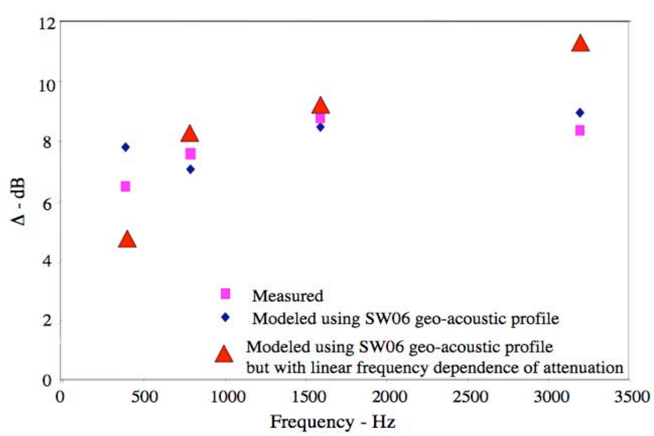

Figure 3: Comparison of $\Delta AN_{SW06,CO}$ to $\Delta L_{SW06,CO}$

Figure 3 compares the measured $\Delta AN_{NJCS,CO}$ and modeled $\Delta L_{NJCS,CO}$ values. $\Delta AN_{NJCS,CO}$ represents the difference of measured wind-driven ambient noise for the New Jersey shelf location and reported deep water values.[4] $\Delta L_{NJCS,CO}$ represents the modeled difference where the modeled results use the seabed parameter values infered from the inversion analyses in ref. 1. The $\Delta AN_{NJCS,CO}$ values lie approximately between 6 and 8 dB in the 400-3200 Hz band, and the $\Delta L_{NJCS,CO}$ values also lie between

about 6 and 8 dB. In this sense the modeled results are in good agreement with the measured values. Figure 3 includes the result of making the frequency dependence of the attenuation for the New Jersey site seabed linear with α=0.55 dB/m at 1 kHz. An attenuation that depends linearly with frequency causes the modeled $\Delta L_{NJCS,CO}$ to have a spread of about 6 dB over the 500-3000 Hz band, whereas the spread of measured $\Delta AN_{NJCS,CO}$ values is only about 2 dB. Assuming that the sediment sound speed values deduced from the previous analysis[1] are approximately correct, a nonlinear frequency dependence of the sediment attenuation appears to be the reason that the $\Delta AN_{NJCS,CO}$ values have a weak frequency dependence in the 500-3000 Hz band.

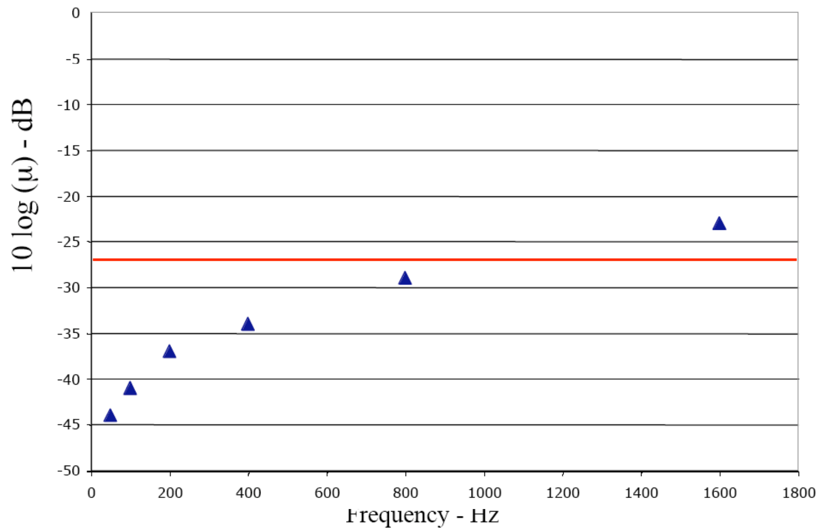

Figure 4: Inferred frequency dependence of the bottom backscatter strength using the inferred geoacoustic values and an assumed Lamberts law angle dependence. The red line is set at -27 dB for purposes of comparison.

Figure 4 shows the inferred frequency dependence of the bottom backscatter strength using the inferred geoacoustic values and an assumed Lamberts law angle dependence. A reverbeation model that uses a boradband normal mode appraoch was used to fit measured reverbeation data[5] taken near the experimental area discussed in ref. 1. The inferred frequency dependence is similar to that reported for an analysis of reverberation data taken in the East China Sea where the sediment properties are similar to those observed for the New Jersey continetial shelf.[6] There are potential ambuguities that can arise in the assumption of Lambert's law for seabed scattering and work in the area of determining an appropriate scattering kernel is of significant interest in the ocean acoustics community.

IMPACT/APPLICATIONS

One potential impact of this research is too add to the experimental knowledge defining the frequency dependence of seabed attenuation which can serve as a test for existing and future theoretical models of sound propagation in marine sediments. A second impact is that the ground truth measurements of statisitics of environmental parameter values compared with computed marginal distributions could serve as a means to properly define uncertainty. Further, the ambient noise modeling may serve as a means to validate other methods of environmental inference. A fourth potential impact is that these studies may assist in understanding how to optimally combine advance propagation models (non-separable and 3-D) and information inference methods as one proceeds to study ocean waveguides with increasing complexity and inhomogeneity.

TRANSITIONS

Transitions of this research may include inversion model development that gives mean and standard deviations for selected environmental and sonar parameter values.

RELATED PROJECTS

Propagation and ambient noise studies in deep water environments. Computations of environmental uncertainty in shallow and deep ocean environments.

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